11 CHARACTERISTICS OF SPECIFIC MODES

There are certain operational modes of the FGS that have been implemented in different ways in different airplanes and systems. The following sections provide guidance and interpretative material that clarifies the operational intent for these modes and provide criteria that have been shown to be acceptable in current operations. The guidance in this section does not preclude other mode implementations.

Pilot understanding of the mode behavior is especially important to avoid potential confusion and should be clearly annunciated as described in Section 9.2, Flight Guidance Mode Selection, Annunciation, and Indication.

11.1 Lateral Modes

This section discusses modes that are implemented in many flight guidance systems that are used primarily for lateral/directional control of the airplane. The criteria below identify acceptable mode operation based on past operational experience gained from the use of these modes.

11.1.1 Heading or Track Hold

In the Heading or Track Hold mode, the FGS should maintain the airplane heading or track. For the situation when the airplane is in a bank when the Heading or Track Hold mode is engaged, the FGS should roll the airplane to a wings-level condition and maintain the heading or track when wings-level is achieved (typically less than five degrees of bank angle).

11.1.2 Heading or Track Select

In the Heading or Track Select mode, the FGS should expeditiously acquire and maintain a 'selected' heading or track value consistent with occupant comfort. When the mode is initially engaged, the FGS should turn the airplane in a direction that is the shortest heading (or track) change to acquire the new heading (or track). Once the heading/track select mode is active, changes in the selected value should result in changes in heading/track. The FGS should always turn the airplane in the same direction as the sense of the selected heading change (e.g., if the pilot turns the heading select knob clockwise, the airplane should turn to the right), even if the shortest heading (or track) change is in the opposite direction. Target heading or track value should be presented to the flight crew.

11.1.3 Lateral Navigation Mode (LNAV)

In the LNAV mode, the FGS should acquire and maintain the lateral flight path commanded by a flight management function (that is, FMS or equivalent).

If the airplane is not established on the desired lateral path or within the designed path capture criteria when LNAV is selected, the FGS LNAV mode should enter an armed state. The FGS should transition from the armed state to an engaged state at a point where the lateral flight path can be smoothly acquired and tracked.

For an FGS incorporating the LNAV mode during the takeoff or go-around phase, the design should specify maneuvering capability immediately after takeoff, and limits, should they exist. After takeoff or go-around, maneuvering should be based upon aircraft performance with the objective to prevent excessive roll attitudes where wingtip / runway impact becomes probable, yet satisfy operational requirements where terrain and / or thrust limitations exist.

11.2 Vertical Modes

This section discusses modes that are implemented in many flight guidance systems that are used primarily for pitch control of the airplane. The criteria identified reflect operational experience gained from the use of these modes.

To avoid unconstrained climbs or descents, for any altitude transitions when using applicable vertical modes, the altitude select controller should be set to a new target altitude before the vertical mode can be selected. If the design allows the vertical mode to be selected before setting the target altitude, then consideration should be given to the potential vulnerability of unconstrained climb or descent leading to an altitude violation or Controlled Flight into Terrain. Consideration should also be given to appropriate annunciation of the deviation from previously selected altitude and / or subsequent required pilot action to reset the selected altitude.

11.2.1 Vertical Speed Mode

In the Vertical Speed mode, the FGS should smoothly acquire and maintain a selected vertical speed.

Consideration should be given to:

- the situation where the selected value is outside of the performance capability of the airplane, or
- use of vertical speed mode without autothrust,

potentially leading to a low-speed or high-speed condition, and corresponding pilot awareness vulnerabilities. See Section 10.4, Speed Protection, for discussion of acceptable means of compliance when dealing with such situations.

11.2.2 Flight Path Angle Mode

In the Flight Path Angle mode, the FGS should smoothly acquire and maintain the selected flight path angle.

Consideration should be given to:

- the situation where the selected value is outside of the performance capability of the airplane, or
- use of flight path angle mode without autothrust,

potentially leading to a low-speed or high-speed condition, and corresponding pilot awareness vulnerabilities. Acceptable means of compliance have included a reversion to an envelope protection mode or a timely annunciation of the situation.

11.2.3 Airspeed (IAS)/Mach Hold [Speed on elevator]

In the Airspeed/Mach Hold mode, the FGS should maintain the airspeed or Mach at the time of engagement.

11.2.4 Airspeed (IAS)/Mach Select Mode [Speed on elevator]

In the Airspeed/Mach Select mode, the FGS should acquire and maintain a selected airspeed or Mach. The selected airspeed or Mach may be either pre-selected or synchronized to the airspeed or Mach at the time of engagement.

11.2.5 Flight Level Change (FLCH) [Speed on elevator]

In the FLCH mode, the FGS should change altitude in a coordinated way with thrust control on the airplane. The autopilot/flight director will typically maintain speed control through elevator. The autothrust function, if engaged, will control the thrust to the appropriate value for climb or descent.

11.2.6 Altitude Capture Mode

The Altitude Capture mode should command the FGS to transition from a vertical mode to smoothly capture and maintain the selected target altitude with consideration of the rates of climb and descent experienced in service.

In-service experience has shown that certain implementations have the potential to cause pilot confusion that may lead to altitude violations. Accordingly, the following are guidelines for the Altitude Capture mode:

(a) The Altitude Capture mode should be armed at all times to capture the selected altitude. Note: assuming that it is armed at all times, then annunciation of the armed status is not required. If the FGS is in Altitude Capture, it should be annunciated.

(b) The Altitude Capture mode should engage from any vertical mode if the computed flight path will intercept the selected altitude and the altitude capture criteria are satisfied, except as specified during an approach (e.g., when the glidepath for approach mode is active).

(c) Changes in the climb/descent command references, with the exception of those made by the flight crew using the altitude select controller, should not prevent capture of the target altitude.

(d) The Altitude Capture mode should smoothly capture the selected altitude using an acceptable acceleration limit with consideration for occupant comfort.

(e) The acceleration limit may, under certain conditions, result in an overshoot. To minimize the altitude overshoot, the normal acceleration limit may be increased, consistent with occupant safety.

(f) During Altitude Capture, pilot selection of other vertical modes should not prevent or adversely affect the level off at the target altitude at the time of capture. One means of compliance is to inhibit transition to other pilot-selectable vertical modes (except altitude hold, go-around, and approach mode) during altitude capture, unless the target altitude is changed. If glidepath capture criteria are satisfied during altitude capture, then the FGS should transition to glidepath capture.

(g) The FGS should be designed to minimize flight crew confusion concerning the FGS operation when the target altitude is changed during altitude capture. It must be suitably annunciated and appropriate for the phase of flight.

(h) Adjusting the datum pressure at any time during altitude capture should not result in loss of the capture mode. The transition to the pressure altitude should be accomplished smoothly.

(i) If the autothrust function is active during altitude capture the autopilot and autothrust functions should be designed such that the FGS maintains the reference airspeed during the level-off maneuver. For example, if the autopilot changes from speed mode to an altitude capture or control mode, then autothrust should transition to a speed mode to maintain the reference airspeed.

11.2.7 Altitude Hold Mode

The Altitude Hold mode may be entered either by flight crew selection or by transition from another vertical mode.

When initiated by an automatic transition from altitude capture the Altitude Hold mode should provide guidance or control to the selected altitude. The automatic transition should be clearly annunciated for flight crew awareness.

When initiated by pilot action in level flight, the Altitude Hold mode should provide guidance or control to maintain altitude at the time the mode is selected.

When initiated by pilot action when the airplane is either climbing or descending, the FGS should immediately initiate a pitch change to arrest the climb or descent, and maintain the altitude when level flight (e.g., <200 feet/min) is reached. The intensity of the leveling maneuver should be consistent with occupant comfort and safety.

Automatic transition into the Altitude Hold mode from another vertical mode should be clearly annunciated for flight crew awareness.

Any airplane response due to an adjustment of the datum pressure should be smooth.

11.2.8 Vertical Navigation Mode (VNAV)

In the VNAV mode, the FGS should acquire and maintain the vertical commands provided by a flight management function (that is, FMS or equivalent).

If the airplane is not on the desired FMS path when the VNAV mode is selected, the FGS VNAV mode should go into an armed state, or provide guidance to smoothly acquire the FMS path. The flight crew should establish the airplane on a flight profile to intercept the desired FMS path. The FGS should transition from the armed state to an engaged state at a point where the FGS can smoothly acquire and track the FMS path.

When VNAV is selected for climb or descent, the autothrust function (if installed) should maintain the appropriate thrust setting. When leveling after a VNAV climb or descent, the autothrust function should maintain the target speed.

If the aircraft is flying a vertical path (e.g., VNAV Path), then the deviation from that path must be displayed in the primary field of view (i.e., the PFD, ND, or other acceptable display).

The FGS should preclude a VNAV climb unless the Mode Selector Panel altitude window is set to an altitude above the current altitude.

Except when on a final approach segment to a runway:

- The FGS should preclude a VNAV descent unless the Mode Selector Panel altitude window is set to an altitude below the current altitude.
- The FGS should not allow the VNAV climb or descent to pass through a Mode Selector Panel altitude.

(See Section 11.5, Special Considerations for VNAV Approach Operations related to selecting a Target Altitude.)

11.3 Multi-axis Modes

This section discusses modes that are implemented in many flight guidance systems that are used in an integrated manner for pitch, lateral/directional control and thrust management of the airplane. The criterion identified reflects operational experience gained from the use of these modes.

11.3.1 Takeoff Mode

In the take off mode, the vertical element of the FGS should provide vertical guidance to acquire and maintain a safe climb out speed after initial rotation for takeoff. If no rotation guidance is provided, the pitch command bars may be displayed during takeoff roll but should not be considered as providing rotation guidance unless it is part of the intended function.

If rotation guidance is provided, consideration should be given to the need to show that the use of the guidance does not result in a tail strike and should be consistent with takeoff methods necessary to meet takeoff performance requirements up to 35 feet AGL.

The Autothrust function should increase and maintain engine thrust to the selected thrust limits [e.g., full T/O, de-rate].

The FGS design should address all engine and engine-inoperative conditions consistent with the following takeoff system performance after liftoff:

(a) Takeoff system operation should be continuous and smooth through transition from the runway portion of the takeoff to the airborne portion and reconfiguration for en route climb. The pilot should be able to continue the use of the same primary display(s) for the airborne portion as for the runway portion. Changes in guidance modes and display formats should be automatic.

(b) The vertical axis guidance of the takeoff system during normal operation should result in the appropriate pitch attitude, and climb speed for the airplane considering the following factors:

- Normal rate rotation of the airplane to the commanded pitch attitude, at V_R-10 knots for all engines and V_R-5 knots for engine out, should not result in a tail-strike.

- The system should provide commands that lead the airplane to smoothly acquire a pitch attitude that results in capture and tracking of the All-Engine Takeoff Climb Speed, $V_2 + X$. X is the All-Engine Speed Additive from the AFM (normally 10 knots or higher). If pitch limited conditions are encountered, a higher climb airspeed may be used to achieve the required takeoff path without exceeding the pitch limit.

(c) For engine-out operation, the system should provide commands that lead the airplane to smoothly acquire a pitch attitude that results in capture and tracking of the following reference speeds:

- V_2, for engine failure at or below V_2. This speed should be attained by the time the airplane has reached 35 feet altitude.

- Airspeed at engine failure, for failures between V_2 and $V_2 + X$.

- $V_2 + X$, for failures at or above $V_2 + X$. Alternatively, the airspeed at engine failure may be used, provided it has been shown that the minimum takeoff climb gradient can still be achieved at that speed.

If implemented, the lateral element of the takeoff mode should maintain runway heading/track or wings level after liftoff and a separate lateral mode annunciation should be provided.

11.3.2 Go-Around Mode

The vertical element of the FGS Go-around mode should initially rotate the airplane, or provide guidance to rotate the airplane, to arrest the rate of descent. The autothrust function, if installed, should increase thrust and either maintain thrust to specific thrust limits, or maintain thrust for an adequate, safe climb.

The FGS should acquire and maintain a safe speed during climbout and airplane configuration changes. Typically, a safe speed for go-around climb is V_2, but a different speed may be found safe for windshear recoveries (see FAA Advisory Circular AC 25-12). The lateral element of the FGS should maintain heading/track or wings level.

The autothrust function should not exceed thrust limits (e.g., full go-around thrust or de-rated go-around thrust limits) nor reduce thrust, for winds, below the minimum value required for an adequate, safe climb or reduce thrust lever position below a point that would cause a warning system to activate. The initial go-around maneuver may require a significant change in pitch attitude. It is acceptable to reduce thrust to lower the pitch attitude for comfort of the occupants when a safe climb gradient has been established. It should be possible for the pilot to re-select the full thrust value if needed.

The go-around mode should engage even if the MSP altitude is at or below the go-around initiation point. The airplane should climb until another vertical mode is selected or the MSP altitude is adjusted to an altitude above the present aircraft altitude.

The FGS design should address all engine and engine-out operation. The design should consider an engine failure resulting in a go-around, and the engine failure occurring during an all engine go-around.

Characteristics of the go-around mode and resulting flight path should be consistent with manually flown go-around.

11.3.3 Approach Mode

In the Approach mode, the FGS should capture and track a final approach lateral and vertical path (if applicable) from a navigation or landing system (e.g., ILS, MLS, GLS, RNP RNAV – refer to AC 120-28D, AC 120-29A, JAR-AWO and JAR-OPS 1).

The FGS should annunciate all operationally relevant approach mode annunciations. Modes that are armed, waiting for capture criteria to be satisfied, should be indicated - in addition to the active pre-capture mode. A positive indication of the capture of the previously armed mode should be provided.

The FGS may have sub-modes that become active without additional crew selection. An assessment of the significance of these sub-mode transitions to the flight crew should be made. If assessed to be significant (e.g., Flare), positive annunciation of the transition should be provided.

Glideslope capture mode engagement may occur prior to localizer capture. However, it is the flight crew's responsibility to ensure proper safe obstacle/terrain clearance when following vertical guidance when the airplane is not established on the final lateral path.

Additional guidance and criteria is contained in AC 120-29A, AC 120-28D and JAR-AWO.

11.4 Autothrust Modes

This section discusses modes that are implemented in many flight guidance systems that are used primarily for controlling the engines on the airplane. The criterion identified reflects operational experience gained from the use of these modes.

11.4.1 Thrust Mode

In the Thrust mode, the FGS should command the autothrust function to achieve a selected target thrust value.

11.4.2 Speed Mode

In the Speed mode, the FGS should command the autothrust function to acquire and maintain the selected target speed value - assuming that the selected speed is within the speed range of the normal flight envelope. The autothrust system may fly a higher airspeed than the selected target speed during takeoff, or during approach when operating in winds or turbulent conditions.

11.4.3 Retard Mode

If such a mode is installed on a specific aircraft, it should work in the same manner for both automatic and manual landings, when the autothrust function is engaged.

11.5 Special Considerations for VNAV Approach Operations related to selecting a Target Altitude

For approach operations, the FGS vertical modes should allow the pilot to set the target altitude to a missed approach value prior to capturing the final approach segment. This should be possible for capturing from both above and below the final approach segment

For VNAV Path operations, it should be possible to define a descent path to the final approach fix and another path from the final approach fix to the runway with the target altitude set for the missed approach altitude. Appropriate targets and descent points should be identified by the FMS.

11.6 Control Wheel Steering (Control Steering through the Autopilot)

In the Control Wheel Steering (CWS) mode, the FGS allows the flight crew to maneuver the airplane through the autopilot. This has implications for control harmony, stability, and crew awareness that need to be thoroughly addressed.

If provided, a CWS mode should meet the following requirements:

(a) It should be possible for the pilot to maneuver the airplane using the normal flight controls with the CWS mode engaged and to achieve the maximum available control surface deflection without using forces so high that the controllability requirements of §/JAR 25.143(c) are not met.

(b) The maximum bank and pitch attitudes that can be achieved without overpowering the automatic pilot should be limited to those necessary for the normal operation of the airplane.

NOTE: Typically 35 degrees in roll and +20 degrees to -10 degrees in pitch

(c) It should be possible to perform all normal maneuvers smoothly and accurately without nuisance oscillation. It should be possible also to counter all normal changes of trim due to change of configuration or power, within the range of flight conditions in which control wheel steering may be used, without encountering excessive discontinuities in control force which might adversely affect the flight path.

(d) The stall and stall recovery characteristics of the airplane should remain acceptable. It should be assumed that recovery is made with CWS in use unless automatic disengagement of the automatic pilot is provided.

(e) In showing compliance with §/JAR 25.143(f), account should be taken of such adjustments to trim as may be carried out by the automatic pilot in the course of maneuvers that can reasonably be expected. Some alleviation may be acceptable in the case of unusually prolonged maneuvers, provided that the reduced control forces would not be hazardous.

(f) If the use of this mode for takeoff and landing is to be permitted, it should be shown that:

i) Sufficient control, both in amplitude and rate is available without encountering force discontinuities;

ii) Reasonable mishandling is not hazardous (e.g., engaging the automatic pilot while the elevators or ailerons are held in an out-of-trim position);

iii) Runaway rates and control forces are such that the pilot can readily overpower the automatic pilot with no significant deviation in flight path; and

iv) Any lag in aircraft response induced by the CWS mode is acceptable for the intended maneuver.

(g) It should not be possible to revert to the CWS mode by applying an input to the control column or wheel unless the autopilot is in a capture mode (e.g., altitude capture, localizer capture). When the force is released, the autopilot should return to the previously engaged capture mode or to the track mode.

NOTE: CWS, if it is provided, is considered to be an autopilot mode, as it is a specific function of the FGS. However, during CWS operation, it is the pilot and not the autopilot that is in control of the aircraft. Operationally, CWS is identical to the pilot flying the airplane during manual flight. In both cases, it is the pilot who is in actual control of the flight path and speed of the airplane. The only difference is the mechanization of how the actual flight control surfaces are moved. No "automatic" FGS commands are involved during CWS operation. Therefore, sections in this Advisory Circular such as those which discuss Speed Protection and performance objectives should be applied to only those autopilot modes with which the FGS is in control of the flight path of the airplane and should not be applied to CWS.

NOTE: The terminology "Control Wheel Steering" is currently used by industry to describe several different types of systems. This section is meant to apply only toward those systems that are implemented in a manner as described above. For comparison, several other functions that are similar in nature, but functionally very different, to CWS are described below. This section does not apply to functions of these types.

- A Touch Control System (TCS) is a function that is available on many business and commuter aircraft. With a TCS system, a pilot is able to physically disengage the autopilot servos from the flight control system, usually by pushing and holding a button on the control wheel, without causing the autopilot system itself to disengage or lose its currently selected modes. The pilot may then maneuver the airplane as desired using the aircraft's flight control system (i.e., the autopilot servos are not part of the control loop). The pilot is then able to reconnect the autopilot servos to the flight control system by releasing the TCS button. Using the new orientation of the aircraft as a basis, the autopilot will then reassume control the airplane using the same mode selections as were present before the selection of TCS. This type of system on some aircraft is also sometimes referred to as Control Wheel Steering.

- Also different from CWS is what is referred to as a "supervisory override" of an engaged autopilot. With this function, a pilot is able to physically overpower an engaged autopilot servo by applying force to the flight deck controls. With a supervisory override, the autopilot does not automatically disengage due to the pilot input. This allows the pilot to position the airplane as desired using the flight deck controls without first disengaging the autopilot. When the pilot releases the controls, the autopilot reassumes control of the airplane using the same mode selections as were present before the supervisory override.

- The descriptions of TCS and supervisory override are intended to be generic. Specific implementations on various aircraft may vary in some aspects.

11.7 Special Considerations for the Integration of Fly-By-Wire Flight Control Systems and FGS

Speed protection features may be implemented in the fly-by-wire flight control system. However, if speed protection is also implemented within the FGS, it should be compatible with the envelope protection features of the fly-by-wire flight control system. The FGS speed protection (normal flight envelope) should operate to or within the limits of the flight control system (limit flight envelope).

Information should be provided to the flight crew about implications on the FGS following degradation of the fly-by-wire flight control systems.